

COSYSMO-IP

COConstructive SYStems Engineering Cost Model – Information Processing

“Headed in a new direction...”

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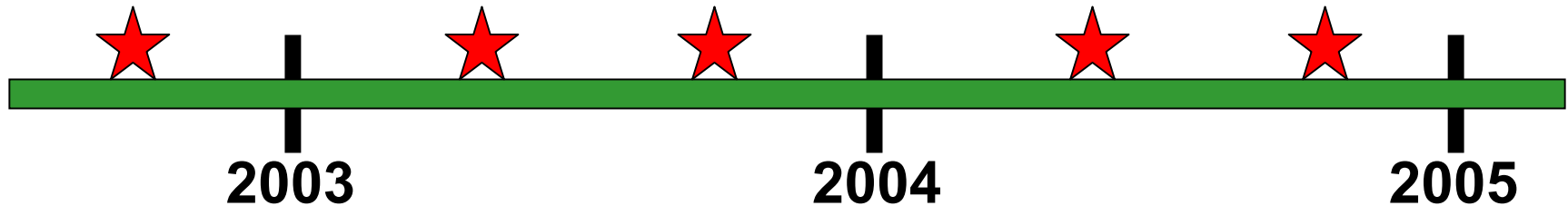
Outline

- **Workshop Objectives**
- **Background on COSYSMO-IP**
- **Outcomes from PSM Meeting (July 2002)**
- **Issues and Answers**
- **Overlap between COSYSMO & COCOMOII**
- **EIA632 & ISO15288**
- **Raytheon myCOSYSMO Prototype**
- **Data Collection Process**

Objectives of the Workshop

- **Reach consensus on resolving the issues**
- **Converge on scope of COSYSMO-IP model**
- **Address INCOSE issues**
- **Address definitions of model parameters**
- **Discuss data collection process**
- **Promote involvement by Affiliates**
- **Define next steps for CSI and INCOSE conferences**

Future Parameter Refinement Opportunities



Driver definitions

Data collection (Delphi)

First iteration of model

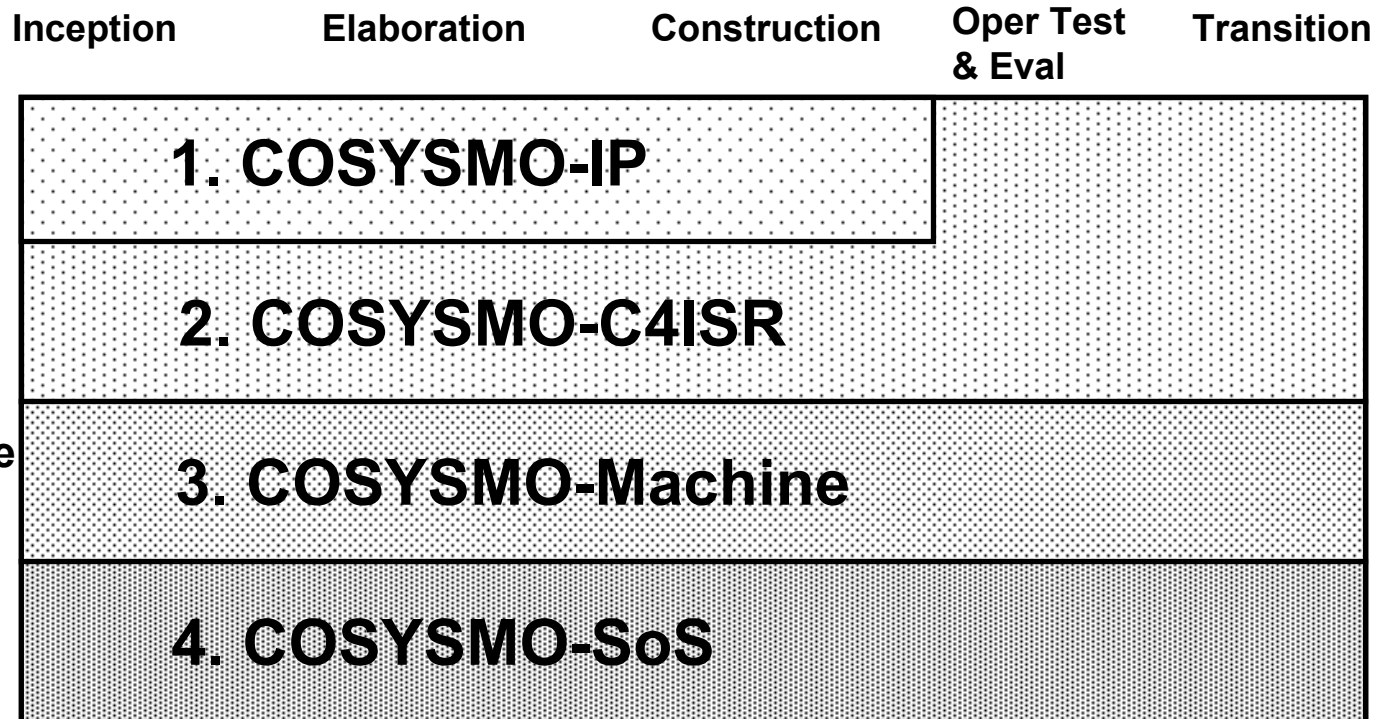
Model calibration

COSYSMO-IP: What is it?

The purpose of the COSYSMO-IP project is to develop an initial increment of a parametric model to estimate the cost of system engineering activities during system development.

The focus of the initial increment is on the cost of systems engineering for information processing systems or subsystems.

Candidate COSYSMO Evolution Path



What Does COSYSMO-IP Cover?

- Includes:
 - System engineering in the inception, elaboration, and construction phases, including test planning
 - Requirements development and specification activities
 - Physical system/information system tradeoff analysis
 - Operations analysis and design activities
 - System architecture tasks
 - Including allocations to hardware/software and consideration of COTS, NDI and legacy impacts
 - Algorithm development and validation tasks
- Defers:
 - Physical system/information system operation test & evaluation, deployment
 - Special-purpose hardware design and development
 - Structure, power and/or specialty engineering
 - Manufacturing and/or production analysis

Outcomes of PSM Meeting

- **Agreement on ConOps**
- **Agreement on COSYSMO-IP scope**
- **Convergence of drivers**
- **Revised driver definitions**

Issues and Answers

Issue

Answer

Application scope



COSYSMO-IP first

Life Cycle scope



**Currently front-end;
negotiable**

Too many size drivers



Reduced from 7 to 4

Conflicting cost drivers



Reduced from 17 to 12

Too software-oriented



IP systems include HW

**Overlap between
COSYSMO and CII**



**Candidate starting point
identified**

Current COSYSMO Scope

Candidate starting point

| EIA Stage | Inception | Development | | Transition |
|----------------|-----------|-------------|--------------|------------|
| | | Elaboration | Construction | |
| Management | 14 | 12 | 10 | 14 |
| Environment/CM | 10 | 8 | 5 | 5 |
| Requirements | 38 | 18 | 8 | 4 |
| Design | 10 | 10 | 16 | 4 |
| Implementation | 8 | 13 | 34 | 19 |
| Assessment | 8 | 10 | 24 | 24 |
| Deployment | 3 | 3 | 3 | 30 |
| TBD | | | | |
| TBD | | | | |
| TBD | | | | |

When doing COSYSMO-IP and COCOMOII, Subtract grey areas prevent double counting.

 = COCOMOII

 = COSYSMO-IP

Mapping of Old to New COSYSMO-IP Drivers

Old (7)

New (4)

Size Factors

Number of System Requirements

Number of Major Interfaces

Number of Technical Performance Measures

Number of Operational Scenarios

Number of Modes of Operation

Number of Different Platforms

Number of Unique Algorithms

Number of System Requirements

Number of Major Interfaces

Number of Operational Scenarios

Number of Unique Algorithms

Requirements understanding

Architecture complexity

Mapping of Old to New COSYSMO-IP Drivers

Old (9)

New (5)

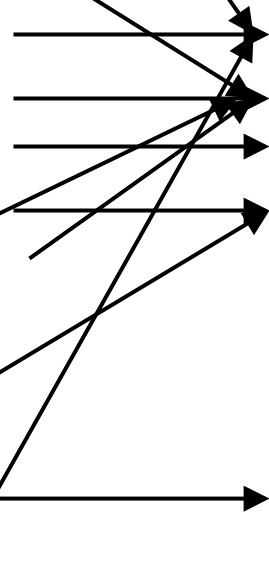
of TPMs

of Platforms

Application Cost Factors

- Requirements understanding
- Architecture complexity
- Level of service requirements
- Legacy Transition complexity
- COTS assessment complexity
- Platform difficulty
- Required business process reengineering
- Technology Maturity
- Physical system/information subsystem tradeoff analysis complexity

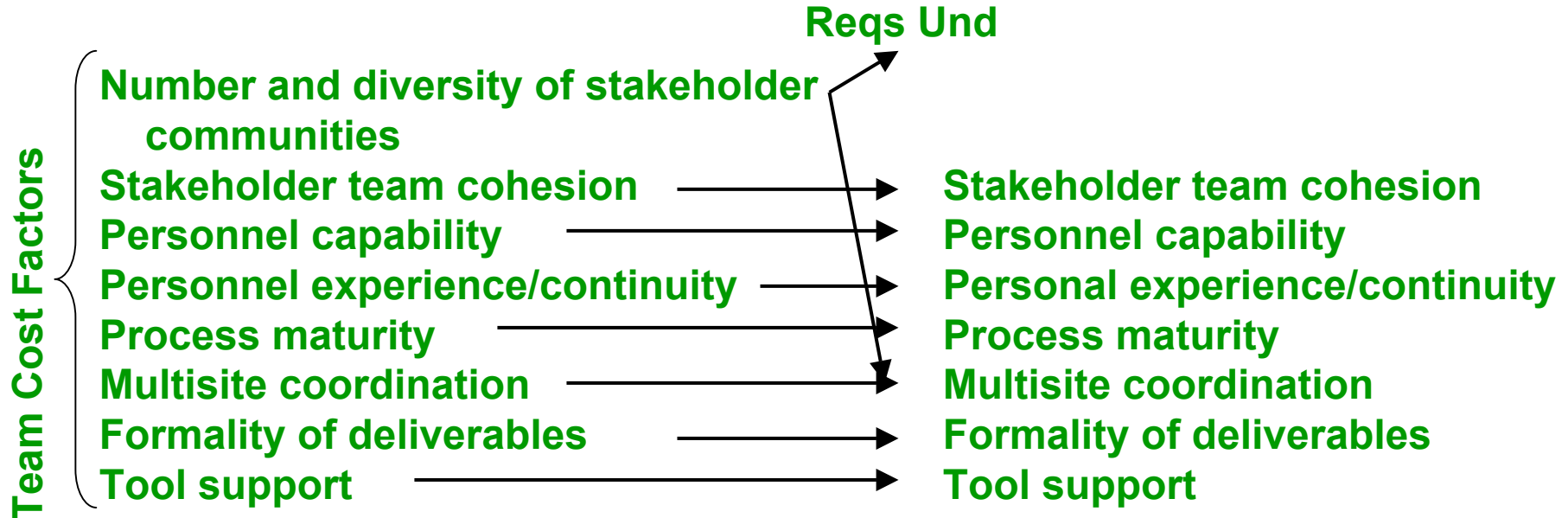
- Requirements understanding
- Architecture complexity
- Level of service requirements
- Migration complexity
- Technology Maturity



Mapping of Old to New COSYSMO-IP Drivers

Old (8)

New (7)





EIA632 & ISO15288

Garry Roedler, INCOSE/LMCO

EIA632/COSYSMO-IP Mapping

COSYSMO-IP Category

EIA632 Requirement

| | |
|---------------------------------------|--------------|
| Supplier Performance | 3 |
| Technical Management | 4-12 |
| Requirements Definition | 14-16 |
| Solution Definition | 17-19 |
| Systems Analysis | 22-24 |
| Requirements Validation | 25-29 |
| Design Solution Verification | 30 |
| End Products Validation - COTS | 33a |

EIA632 Reqs. not included in COSYSMO-IP are: 1,2,13,20,21,31,32,33b



Raytheon myCOSYSMO Prototype

Gary Thomas, Raytheon

Data Collection Process

- **Next Delphi Round is scheduled for Dec '02**
- **Driver feasibility/level of guidance survey results**
- **Other experiences**

Other Open Issues

- **Business Process Reengineering driver**
- **Difference between # of Modes and # of Scenarios**
- **Schedule duration driver**
- **Involvement of Commercial Companies**

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Backup Charts

Modified Rating Scales for Drivers

Number of System Requirements

This driver represents the number of requirements that are typically taken from the system or marketing specification. A requirement is a statement of capability containing a normative verb such as “shall” or “will.” It may be functional, performance, feature, or service-oriented in nature depending on the methodology used for specification. System requirements can typically be quantified by counting the number of applicable “shall’s” or “will’s” in the system or marketing specification.

| | Easy | Nominal | Difficult |
|-----------------------------------|--|---|--|
| No. of System Requirements | - Well specified | - Loosely specified | - Poorly specified |
| | - Traceable to source | - Can be traced to source with some effort | - Hard to trace to source |
| | - Simple to understand | - Takes some effort to understand | - Hard to understand |
| | - Little requirements overlap | - Some overlap | - High degree of requirements overlap |
| | - Familiar | - Generally familiar | - Unfamiliar |
| | - Good understanding of what's needed to satisfy and verify requirements | - General understanding of what's needed to satisfy and verify requirements | - Poor understanding of what's needed to satisfy and verify requirements |

Modified Rating Scales for Drivers

Number of Major Interfaces

This driver represents the number of shared major physical and logical boundaries between system components or functions (internal interfaces) and those external to the system (external interfaces). These interfaces typically can be quantified by counting the number of interfaces identified in either the system's context diagram and/or by counting the significant interfaces in all applicable Interface Control Documents.

| | Easy | Nominal | Difficult |
|--------------------------------|----------------|------------------------|------------------|
| No. of Major Interfaces | - Well defined | - Loosely defined | - Ill defined |
| | - Uncoupled | - Loosely coupled | - Highly coupled |
| | - Cohesive | - Moderate cohesion | - Low cohesion |
| | - Well behaved | - Predictable behavior | - Poorly behaved |

Modified Rating Scales for Drivers

Number of Operational Scenarios

This driver represents the number of operational scenarios that a system must satisfy. Such threads typically result in end-to-end test scenarios that are developed to validate the system satisfies all of its requirements. The number of scenarios can typically be quantified by counting the number of end-to-end tests used to validate the system functionality and performance. They can also be calculated by counting the number of high-level use cases developed as part of the operational architecture.

| | Easy | Nominal | Difficult |
|-------------------------------------|-----------------------------------|---|--|
| No. of Operational Scenarios | - Well defined | - Loosely defined | - Ill defined |
| | - Few end-to-end scenarios (< 10) | - Modest no. of end-to-end scenarios (10 < OS ≤ 30) | - Many end-to-end scenarios (> 30) |
| | - Timelines not an issue | - Timelines a constraint | - Tight timelines through scenario network |

Modified Rating Scales for Drivers

Number of Unique Algorithms

This driver represents the number of newly defined or significantly altered functions that require unique mathematical algorithms to be derived in order to achieve the system performance requirements. As an example, this could include a complex aircraft tracking algorithm like a Kalman Filter being derived using existing experience as the basis for the all aspect search function. Another example could be a brand new discrimination algorithm being derived to identify friend or foe function in space-based applications. The number can be quantified by counting the number of unique algorithms needed to support each of the mathematical functions specified in the system specification or mode description document (for sensor-based systems).

| | Easy | Nominal | Difficult |
|---------------------------------|-----------------------------|--|---|
| No. of Unique Algorithms | - Existing algorithms | - Some new algorithms | - Many new algorithms |
| | - Basic math | - Algebraic by nature | - Difficult math (calculus) |
| | - Straightforward structure | - Nested structure with decision logic | - Recursive in structure with distributed control |
| | - Simple data | - Relational data | - Persistent data |
| | - Timing not an issue | - Timing a constraint | - Dynamic, with timing issues |
| | - Library-based solution | - Some modeling involved | - Simulation and modeling involved |

Modified Rating Scales for Drivers

Requirements understanding

This cost driver rates the level of understanding of the system requirements by all stakeholders including the systems, software, hardware, customers, team members, users, etc...

| Very low | Low | Nominal | High | Very High |
|----------------------------|-------------------------------|----------------------------------|-----------------------------|---|
| Poor, unprecedented system | Minimal, many undefined areas | Reasonable, some undefined areas | Strong, few undefined areas | Full understanding of requirements, familiar system |

Modified Rating Scales for Drivers

Architecture complexity

This cost driver rates the relative difficulty of determining and managing the system architecture in terms of Information Processing platforms, standards, components (COTS/GOTS/NDI/new), connectors (protocols), and constraints. This includes tasks like systems analysis, tradeoff analysis, modeling, simulation, case studies, etc...

| Very low | Low | Nominal | High | Very High |
|--|---|---|---|---|
| Poor understanding of architecture, unprecedented system | Minimal understanding of architecture, many undefined areas | Reasonable understanding of architecture, some weak areas | Strong understanding of architecture, few undefined areas | Full understanding of architecture, familiar system |

Modified Rating Scales for Drivers

Level of service requirements

This cost driver rates the difficulty and criticality of satisfying the Key Performance Parameters (KPP). For example: security, safety, response time, the “illities”, etc...

| | Very low | Low | Nominal | High | Very High |
|-------------|----------------------|---------------------------|--------------------|------------------------|--------------------|
| Difficulty | Simple requirements | Low difficulty | Moderately complex | Difficult requirements | Really complex |
| Criticality | Slight inconvenience | Easily recoverable losses | Some loss | High financial loss | Risk to human life |

Modified Rating Scales for Drivers

Migration complexity

This cost driver rates the complexity of migrating the system from previous system components, databases, workflows, etc, due to new technology introductions, planned upgrades, increased performance, business process reengineering etc...

| Very low | Low | Nominal | High | Very High |
|----------|-----|---|----------------------|---------------------------|
| N/A | N/A | Introduction of requirements is transparent | Difficult to upgrade | Very difficult to upgrade |

Modified Rating Scales for Drivers

Technology maturity

This cost driver rates the relative readiness for operational use of the key technologies.

| Very low | Low | Nominal | High | Very High |
|--------------------------------|--|---|---|--|
| - Still in the laboratory | - Ready for pilot use | - Proven on pilot project and ready for roll-out on production jobs | - Proven through actual use and ready for widespread adoption | - Technology widely used throughout industry |
| TRL 1 & 2 - Concept defined | TRL 3 to 6 - Proof of concept validated | TRL 7 - Concept demonstrated | TRL 8 - Concept qualified | TRL 9 - Mission proven |

Modified Rating Scales for Drivers

Stakeholder team cohesion

Leadership, frequency of meetings, shared vision, approval cycles, group dynamics (self-directed teams, project engineers/managers), IPT framework, and effective team dynamics.

| Very low | Low | Nominal | High | Very High |
|--|--|--|---|--|
| No team cohesion, friction, lack of leadership | Marginally effective team cohesion, some leadership and teamwork | Functional team, good leadership and team dynamics | Strong team cohesion, effective leadership and strong team dynamics | Exceptional team cohesion, extraordinary leadership, strong team dynamics, and solid IPT framework |

Modified Rating Scales for Drivers

Personnel capability

Systems Engineering's ability to perform in their duties and the quality of human capital.

| Very Low | Low | Nominal | High | Very High |
|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|
| 15 th percentile | 35 th percentile | 55 th percentile | 75 th percentile | 90 th percentile |

Personnel experience/continuity

The applicability and consistency of the staff over the life of the project with respect to the customer, user, technology, domain, etc...

| Very low | Low | Nominal | High | Very High |
|--------------------|---|----------------------------------|----------------------------------|-----------------------------------|
| Less than 2 months | 1 year continuous experience, other technical experience in similar job | 3 years of continuous experience | 5 years of continuous experience | 10 years of continuous experience |

Modified Rating Scales for Drivers

Process maturity

Maturity per EIA/IS 731, SE CMM or CMMI.

| Very low | Low | Nominal | High | Very High | Extra High |
|----------------------|----------------------|---------|---------|-----------|------------|
| Level 1 (lower half) | Level 1 (upper half) | Level 2 | Level 3 | Level 4 | Level 5 |

Multisite coordination

Location of stakeholders, team members, resources (travel).

| | Very low | Low | Nominal | High | Very High | Extra High |
|---------------------------------|------------------|-------------------------------|-----------------------------|-----------------------------------|--|------------------------|
| SITE: Collocation | International | Multi-city and multi-national | Multi-city or multi-company | Same city or metro area | Same building or complex | Fully located |
| SITE: Communications | Some phone, mail | Individual phone, FAX | Narrowband e-mail | Wideband electronic communication | Wideband electronic communication, occasional video conference | Interactive multimedia |

Modified Rating Scales for Drivers

Formality of deliverables

The breadth and depth of documentation required to be formally delivered.

| Very low | Low | Nominal | High | Very High |
|---------------|-----------------|-----------------|--|---|
| General goals | Some conformity | Some relaxation | Partially streamlined process, occasional relaxation | Rigorous, follows customer requirements |

Tool support

Use of tools in the System Engineering environment.

| Very low | Low | Nominal | High | Very High |
|-------------|-------------------------------------|--------------------------------------|--|---|
| No SE tools | Simple SE tools, little integration | Basic SE tools moderately integrated | Strong, mature SE tools, moderately integrated | Strong, mature proactive SE tools integrated with process |

Old (16)

New (9)

Size

Number of System Requirements

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Number of Operational Scenarios

Number of Modes of Operation

Number of Different Platforms

Number of Unique Algorithms

Requirements understanding

Architecture complexity

Level of service requirements

Legacy Transition complexity

COTS assessment complexity

Platform difficulty

Required business process

reengineering

Technology Maturity

Physical system/information
subsystem tradeoff analysis
complexity

Number of System Requirements

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Number of Unique Algorithms

Requirements understanding

Architecture complexity

Level of service requirements

Migration complexity

Technology Maturity

Cost

of Modes vs. # of Scenarios

Wireless Communications example

Modes:

TDMA

CDMA

GSM

Scan for channel

Scenarios:

Voice

E911

E-mail

Web browsing